Chapter 4: Beach Monitoring and Assessment

This chapter describes the performance criteria and technical guidance related to monitoring and assessment.

4.1 Performance Criteria

Table 4-1 summarizes the general and specific requirements of three performance criteria (2 through 4) related to monitoring and assessment activities.

Table 4-1. Summary of Monitoring Performance Criteria

Performance Criteria		Chapter Section
General Requirements	**Specific Requirements**	
Develop Tiered Monitoring Plan (Performance Criterion 2). Performance Criterion 2 requires development of an adequate tiered monitoring plan.	• In the monitoring plan, address frequency and location of monitoring and assessment of coastal water, based on a variety of factors: - Periods of recreational use of the waters - Nature and extent of use during certain periods - The proximity to known point and nonpoint sources of pollution - Any effect of storm events on the waters • In the monitoring plan, adequately address required monitoring elements: public health; number of beaches; existing monitoring data; public review; adaptive monitoring approach; and quality control. Develop appropriate quality control policies and procedures and submit adequate quality management plans and quality assurance plans to EPA for approval.	4.2

Table 4-1. (continued)

Performance Criteria		Chapter Section
General Requirements	**Specific Requirements**	
Monitoring Report Submission and Delegation (Performance Criterion 3). Performance Criterion 3 requires states, tribes, and local governments to develop a mechanism to collect and report their monitoring data in timely reports and, in the case of states, to document any delegation of monitoring responsibilities that might have been made to local governments.	• States, tribes, and local governments must report their monitoring data to the public, EPA, and other agencies in a timely manner. States should coordinate closely with local governments to ensure that monitoring information is submitted in a consistent fashion. • States, tribes, and local governments must report their monitoring data annually to EPA. Reported data must be consistent with the list of required data elements in appendix E. • If monitoring responsibilities are delegated to local governments, the state grant recipient must describe the process by which the state may delegate to local governments responsibility for implementing the monitoring program.	4.3
Assessment Methods and Procedures (Performance Criterion 4). Performance Criterion 4 requires the development of detailed methods and assessment procedures.	• States, tribes, or local governments must: - Adequately address and submit to EPA methods for detecting levels of pathogens and pathogen indicators that are harmful to human health in coastal recreation areas. - Provide documentation to support the validity of methods other than those currently recommended or approved by EPA. - Identify and submit to EPA assessment procedures for identifying short-term increases in pathogens and pathogen indicators that are harmful to human health in coastal recreation areas.	4.4

4.2 Tiered Monitoring Plan

Once states and tribes have ranked their beaches, they are required to develop and submit an adequate tiered monitoring plan. They can follow the requirements and recommendations in this chapter to develop and implement the tiered monitoring plan based on the beach classification. This section includes an example of a three-tiered plan as the recommended approach. A state, tribe, or local government may develop a tiered approach different from that recommended, but it must demonstrate how the plan meets the performance criterion for an adequate tiered monitoring plan.

4.2.1 Monitoring Design

An adequate monitoring plan must address the required monitoring elements discussed below. Other aspects discussed in this section also should be considered.

Required Monitoring Elements

EPA recognizes that variation in bacterial densities is one of the main technical challenges that beach managers face when designing effective monitoring programs and interpreting sampling results. There is substantial site-specific variability (both spatial and temporal) in bacterial counts. Accordingly, monitoring plans should be tailored to individual circumstances.

The monitoring plan must adequately address the following elements:

- *Public health*. Protection of public health is the primary objective in designing a beach monitoring program.

- *Maximum number of beaches*. As noted earlier, the BEACH Act requires states and tribes to identify their beaches ("list of waters") that may be subject to the program and identify the factors used in prioritizing their monitoring and notification efforts. EPA's strongly encourages states and tribes to include the maximum number of beaches in their list of waters and their monitoring program. Because of this, EPA recommends a tiered monitoring approach. This policy allows flexibility to states and tribes, recognizing that there might not be uniform monitoring requirements for all beaches. EPA believes this approach is preferable to setting strict minimum requirements and risking omission of a large number of beaches from the program.

- *Public review*. As a prerequisite for receiving an implementation grant, the BEACH Act requires states, tribes, and local governments to provide the public with an opportunity to review the monitoring and notification program through a process that provides for public notice and an opportunity to comment. The monitoring plan is one aspect that must be reviewed as part of the performance criterion for public review that is explained in section 2.2.9.

- *Existing monitoring data*. EPA recognizes that there is significant site-specific variability in bacterial densities. Many states, tribes, and local governments have a well-established monitoring program with detailed understanding of their water quality conditions. If reliable monitoring information exists, it should be documented and used during the development of the monitoring program.

- *Adaptive sampling approach*. Monitoring programs should be flexible enough to allow states and tribes to increase their sampling frequency, locations, and other factors to accommodate demands for new information as the need arises.

- *Quality Control*. States, tribes, and local governments must develop appropriate quality control policies and procedures and submit adequate quality management plans and quality assurance plans to EPA for approval. This section describes data quality requirements for the BEACHES program.

Quality Control

EPA regulations at 40 CFR 31.45 governing grants to states, tribes, and local governments provide as follows:

> If the grantee's project involves environmentally related measurements or data generation, the grantee shall develop and implement quality assurance practices consisting of policies, procedures, specifications, standards, and documentation sufficient to produce data of quality adequate to meet project objectives and to minimize loss of data due to out-of-control conditions or malfunctions.

The work performed under the BEACH grants involves environmentally related measurements and data generation. To comply with 40 CFR 31.45, states, tribes, and local governments must develop and implement a quality management system that is sufficient to produce data of a quality adequate to meet the Beaches project objectives.

EPA is committed to ensuring the quality of environmental data used in its decision-making process and in activities supported by EPA. As a result, EPA has developed an Agency-wide quality system to ensure that environmental data are of sufficient quantity and quality to support the data's intended use. The Office of Water has in turn developed a Quality Management Plan for OW activities (the OW QMP) that is consistent with the EPA quality system (USEPA, 2001c).

Three specific requirements must be met to comply with Performance Criterion 2:

1. States, tribes, and local governments must submit quality system documentation that describes the quality system implemented by the state, tribe, or local government. It may be in the form of a QMP or equivalent documentation.

2. States, tribes, and local governments must submit a quality assurance project plan (QAPP) or equivalent documentation. A QAPP is a commonly used form of documentation for primary data collection. It is a technical planning document that defines the objectives of a project or continuing operation, as well as the methods, organization, and quality management activities necessary to meet the goals of the project or operation. It serves as the blueprint for

implementing the data collection activity to ensure that the technical and quality goals of the operation are met. It also provides the necessary link between the required data quality constraints and the sampling and analysis activities to be conducted.

3. States, tribes, and local governments are responsible for submitting documentation of the quality system and the QAPP for review and approval by the Quality Assurance Officer or his designee before environmental measurements (primary or secondary) are taken.

Each of these components is based on requirements previously established in the OW QMP. Additional quality control information is available in Appendix H. Applicants should contact the EPA Regional Quality Assurance Officer for more detailed guidance.

Specific Monitoring Guidelines and Examples

The following sections provide EPA's current recommended guidelines and examples that a state, tribe, or local government should consider in its monitoring plan. (The letters *A*, *B*, *C*, and *D* correspond to the parts of table 4-2 that summarize these recommendations.)

A. When to Conduct Basic Sampling

To evaluate compliance with water quality standards, EPA recommends that samples be taken at least once per week during the swimming season. Sampling should begin 1 month before the start of the swimming season. These sampling frequencies may be altered depending on the circumstances.

For Tier 1 beaches, EPA recommends that water quality samples be taken one or more times per week during the swimming season. Many agencies sample more frequently to minimize the uncertainty in their sampling; EPA recommends more frequent sampling where circumstances warrant. For Tier 2 beaches, EPA recommends that water quality samples be taken once per week during the swimming season. However, less frequent sampling might be possible depending on proximity to suspected pollution sources, beach use, historical water quality data, and other risk factors. For Tier 3 beaches, a minimum sampling frequency consistent with other ambient water quality sampling programs could be conducted for a limited time (one to two years). However, these areas should be sampled to determine whether they should be reclassified as Tier 1 or Tier 2 beaches or dropped from the program.

B. When to Conduct Additional Sampling

This section provides examples of some sampling approaches that could be used to address several typical scenarios.

Table 4-2. EPA Recommended Tiered Sampling Design for Beach Managers

		Tier 1	Tier 2	Tier 3
A. When to Conduct Basic Sampling		At least 1 month before start of swimming season until end of swimming season. Recommended sampling frequency is one or more times per week during the swimming season.	At least 1 month before start of swimming season until end of swimming season. Recommended sampling frequency is one time per week during the swimming season. However, less frequent sampling might be adequate depending on proximity to suspected sources, beach use, historical water quality data, and other risk factors.	At least 1 month before start of swimming season until end of swimming season. A minimum sampling frequency, consistent with other ambient water quality sampling programs, could be used for a limited time. Areas should be sampled to determine whether they should be reclassified or dropped from the program
B. When to Conduct Additional Sampling	After a water quality standard is exceeded	When a bacterial concentration exceeds a water quality standard, a state, tribe, or local government must immediately either issue a public notification or resample. If a sample result is determined to be accurate and standards are indeed being exceeded, the agency must issue its public notification. Resampling is acceptable after exceedance of a state or tribal water quality standard where there is reason to doubt the accuracy or certainty of the first sample, based on predefined quality assurance measures. EPA recommends that additional samples be taken as soon as possible if the first sample exceeds water quality standards.		
	After a sewage spill or pollution event	EPA recommends that additional sampling be conducted immediately after a sewage spill or a significant pollution event where the potential exists that indicator levels may be expected to exceed standards. EPA strongly recommends that states and tribes consider beach closures when a sewage spill or major leaks are suspected.		
	Reopening after advisory or closure	Additional sampling should be conducted to determine whether a public notification can be discontinued (beach advisory, posting, or closure). Since an advisory should not be lifted without sample results that show the applicable water quality standards have been met, an agency may want to complete accelerated sampling to remove a health advisory sooner rather than waiting until the next routine sampling results are received.		
	After a heavy rainfall event	EPA recommends that samples be taken after a heavy rainfall, particularly if a valid preemptive standard is not in place.		NA
C. Where to Collect Samples		Middle of typical bathing area. Near known and potential pollution sources. For short beaches, one sample at a point corresponding to each lifeguard chair, or one for every 500 m of beach. For long beaches (> 8 km [5 miles]), sample at most highly used areas, and spread out samples along the entire beach.	Middle of typical bathing area. Near known and potential pollution sources.	Middle of typical bathing area. Near potential pollution sources.
D. What Depth to Sample		Knee depth.	Knee depth.	Knee depth.

B1. After a water quality standard is exceeded

When a bacterial concentration exceeds a water quality standard, a state, tribe, or local government must immediately either issue a public notification or resample, if there is reason to doubt the accuracy or certainty of the first sample. Public notification procedures (beach advisories, postings, and closings) are discussed more fully in chapter 5.

- If a sample result is determined to be accurate and standards are indeed being exceeded, the agency must issue its public notification. Notification should remain in effect until resampling indicates that water quality standards are no longer being exceeded and approved QA/QC requirements are being met for sample accuracy. When standards are no longer being exceeded, the basic sampling approach may be resumed, provided no heavy rainfall or other pollution events have occurred.

- Resampling is acceptable after a state or tribal water quality standard has been exceeded if there is reason to doubt the accuracy or certainty of the first sample, based on predefined QA measures. EPA recommends that additional samples be taken as soon as possible if the first sample exceeds water quality standards.

    - If possible, the resampling should be completed immediately after a water quality "exceedance" is detected, with results obtained no more than 48 hours after the routine monitoring results indicate an exceedance.

    - If the second sample indicates that a water quality standard has been exceeded, then states, tribes, and local governments must provide prompt public notification.

    - Resampling policies should be carefully reviewed to ensure that the program is still protective of public health by limiting public exposure to poor water quality. Resampling is more reasonable when (1) sampling results at the beach have shown that, historically, water quality has consistently met water quality standards and (2) no known or potential sources of fecal contamination affect beach water quality.

B2. After a sewage spill or pollution event

For all beaches, EPA recommends that additional sampling be conducted immediately after a sewage spill or a significant pollution event where the potential exists that indicator levels may be expected to exceed standards. EPA strongly recommends that states, tribes, and local governments consider beach closure when a sewage spill or major leaks are suspected. (Beach closures are discussed more fully in chapter 5.)

Additional sampling should be conducted before a beach is reopened after a closure because of a known sewage spill. Since a beach should not be reopened without sampling results showing that health standards are being met, an agency should complete additional sampling of a beach to ensure the spill has been mitigated before reopening the beach.

B3. Reopening after an advisory or a closure

Additional sampling should be conducted to determine whether a public notification (beach advisory, posting, or closure) can be discontinued. Since an advisory should not be lifted without sample results showing that the applicable water quality standards have been met, an agency might want to complete accelerated sampling to remove a health advisory sooner rather than

waiting until the next routine sampling results are received. (Additional sampling might not be necessary if a preemptive advisory or closing already exists. Preemptive advisories are discussed more fully in section 5.3.2.)

B4. After a heavy rainfall event
At Tier 1 and Tier 2 beaches, EPA recommends that additional samples be taken after a heavy rainfall, particularly if a state, tribe, or local government does not have a preemptive standard in place.

B5. Other circumstances
Additional sampling should be conducted to determine the extent to which a beach is affected by bacterial densities that are above the applicable water quality standards. When routine monitoring at a sample location indicates elevated bacterial densities, additional sampling may be conducted to determine the *extent* of the water quality problem. A good example of this practice was the adaptive sampling strategy completed by the local health agency in Huntington Beach, California, in 1999. By adding sampling stations and increasing the frequency of sampling, the health agency was able to define the extent of poor water quality and the portion of the beach that could remain open for swimming. Defining the extent of the poor water quality more effectively protects public health and might provide valuable information for source identification and mitigation.

C. Where to Collect Samples

During the Data Quality Objective (DQO) Process, agencies should consider spatial and temporal variation as well as resource constraints in setting forth optimal sampling locations. EPA's recommendation for all beaches is that samples be taken in the middle of a typical bathing area. At Tier 1 beaches, agencies should consider the following:

- If the beach is short, samples should be taken at a point corresponding to each lifeguard chair, or one for every 500 meters of beach.

- If the beach is long (more than 5 miles), samples should be taken at the most highly used areas and spread out along the entire beach.

In addition, all Tier 1 and 2 beaches should be sampled near known and potential pollution sources, whereas Tier 3 beaches should be sampled near potential pollution sources.

D. What Depth to Sample

EPA's recommendation for all beaches is that samples be taken at knee depth. States and tribes are encouraged to sample at the same depth for all beaches to ensure consistency and comparability among samples. For example, if beach classification changes over time, the samples

would remain comparable because of the consistency in sample depth. At Tier 1 beaches, additional samples may be taken as necessary at a particular beach (e.g., waist depth, ankle).

Table 4-2 presents *examples* of monitoring options based on the beach classification (chapter 3). The table includes suggestions for Tier 1, 2, and 3 beaches on when to conduct basic sampling, when to conduct additional sampling, where to collect samples, and at what depth to sample.

Current Research

Monitoring program design is an essential part of any sampling program. Ongoing beach-related research efforts are being conducted by EPA, the U.S. Geological Survey (USGS), state and local agencies, tribes, and other scientists and organizations. For example, EPA's Office of Research and Development (ORD) is undertaking a study at marine, estuarine, and freshwater beaches to develop a statistically valid monitoring protocol that takes into account elements that contribute to the uncertainty associated with sampling bathing beach waters, such as tides, wind, solar radiation, bather density, temporal and spatial factors, rainfall, and the proximity of point and nonpoint sources of pollution. New data collected during the summer of 2000 are being evaluated to recommend a monitoring protocol that minimizes uncertainty about the quality of bathing waters while requiring the fewest number of samples possible. When published, this protocol will provide additional information to assist in determining when, where, and how many samples should be taken and how the monitoring data should be analyzed. The data quality objectives of this study are provided at http://www.epa.gov/nerlcwww/bch_dqo.pdf. The guidance will be updated periodically to reflect the results of ongoing research.

4.2.2 Other Elements of a Monitoring Plan

Monitoring Design Considerations

Information Sources

One information source for monitoring recommendations is a National Research Council (NCR) report that recommended ways to improve the usefulness of monitoring information. It is contained in appendix H. The NRC report addresses such topics as monitoring objectives, testing hypotheses and statistical methods, analytical methods and sampling designs, evaluation of monitoring program performance, and data analysis.

Another information source is EPA's Consolidated Assessment and Listing Methodology (CALM). During the monitoring design process, states and tribes should consider how the beach water quality monitoring results will be used in conjunction with other state monitoring efforts. For example, the information might also be used to help characterize ambient waters for activities such as 305(b) reports or watershed assessments. Although such considerations are beyond the scope of this document, these topics are addressed in EPA's draft CALM document (USEPA, 2002).

DQO Process

When monitoring data are being used in making a decision by selecting between two clear alternatives (e.g., close a swimming beach or not close it), EPA recommends that states and tribes consider using the systematic planning tool called the Data Quality Objectives (DQO) Process. The DQO Process is an iterative process used to develop qualitative and quantitative statements that

- Clarify study objectives.
- Define the appropriate types of data.
- Specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions (USEPA, 2000a).

The final outcome of the monitoring design process is a design for collecting data (e.g., the number of samples to collect; when, where, and how to collect samples; variables to be measured; and quality assurance (QA) and quality control (QC) activities needed to manage sampling design and measurement errors), together with limits on the probabilities of making decision errors. The design and oversight activities that will be used during the beach monitoring program to ensure that the samples are collected and analyzed appropriately to meet the acceptance or performance

criteria are then written down in one or more planning documents. These materials form the quality system documentation to be submitted for consideration of a grant award.

Staffing Monitoring Programs

A monitoring plan should include an adequate staffing plan for the beach monitoring program. EPA recommends that professional staff from state, tribal, and local agencies maintain primary responsibility for design and oversight of beach monitoring. Citizen volunteers may also be used to perform supplemental beach monitoring program functions. For example, volunteers could be used to provide more intensive monitoring at high-priority beaches or to help with monitoring at lower-priority beach areas where regular staff might not be available. Appendix I provides additional information on volunteer monitoring programs.

Training Monitoring Staff

Once the monitoring plan has been developed, the staff who will implement the program should receive specific training. Whether drawn from the ranks of professional staff or volunteers, the personnel responsible for sample collection and environmental measurements at the beach, as well as those performing the bacterial indicator analyses, should be trained for those activities. The quality of information produced by a monitoring program depends on the quality of the work undertaken by field and laboratory staff. Separate training programs should be developed for field staff, laboratory staff, and others involved in the monitoring program. Training should continue for as long as the monitoring program is in action. Additional information on training is provided in appendix I.

Managing Data

One of the most important aspects of a monitoring program is management of the data, from the collection process through the data analysis. Data management activities include documenting the nature of the data and subsequent analyses in a manner that permits the data in one set to be compared with those in other data sets. Data management also includes handling and storing both hard copies and electronic files containing field and laboratory data. A data management system that will address the multiple needs of data users should be designed at the beginning of the monitoring program. It is important to understand and comply with all state or tribal agency policies and standards regarding data collection and generation.

Providing data to update national ambient water quality databases with the results of local beach monitoring is an example of the need to transfer data between states and EPA. EPA strongly encourages beach managers (and volunteer monitors) to add their data to the Agency's storage and retrieval (STORET) database. States, tribes, and local governments can add their data to an existing "state STORET" database, create a "state or local STORET" database, or create a data system to store data. EPA maintains two data management systems containing water quality

information for the nation's waters: the Legacy Data Center and STORET. The Legacy Data Center, or LDC, contains historical water quality data dating back to the early part of the 20th century and collected up to the end of 1998. STORET contains data collected beginning in 1999, along with older data that have been properly documented and migrated from the LDC. Both systems contain raw biological, chemical, and physical data on surface water and ground water collected by federal, state, and local agencies; Indian tribes; volunteer groups; academics; and others. Each sampling result in the LDC and in STORET is accompanied by information on where the sample was taken (latitude, longitude, state, county, Hydrologic Unit Code, and brief site identification), when the sample was gathered, the medium sampled (e.g., water, sediment, fish tissue), and the name of the organization that sponsored the monitoring. Staff working with the database should have expertise and training in the software, as well as in the procedures for data transport, file transfer, and system maintenance. Additional information on STORET can be found at http://www.epa.gov/storet/.

The operation of the data management system should include QA oversight and QC procedures. If changes in hardware or software become necessary during the course of the project, the data manager should obtain the most appropriate equipment and test it to verify that the equipment can perform the necessary jobs. Appropriate user instructions and system documentation should be available to all staff using the database system. The development of spreadsheet, database, and other software applications involves performing QC reviews of input data to ensure the validity of computed data.

Program Implementation and Oversight

The monitoring program should be implemented and its effectiveness assessed at regular intervals. The purpose of assessments (such as surveillance, readiness reviews, technical system audits, performance evaluations, and audits of data quality) is to determine whether the established QC procedures are being used and how the program is operating. Checklists or reviews of program documentation and reports can be used to evaluate different aspects of the program. The types and number of assessments to be performed can be documented in the monitoring program oversight plan. In addition, the program should clearly provide for the authority of the assessor (e.g., a QA officer) to stop work and should identify under what conditions this may occur.

The QA program should include procedures for identifying and defining a problem, assigning responsibility for investigating the problem, determining the cause of the problem, assigning responsibility for implementing corrective action, and assigning responsibility for determining the effectiveness of the corrective action and verifying that the corrective action has eliminated the problem. Supervision is important during the program. To provide advice and identify problems when they occur, personnel providing oversight to technical staff should be well versed in the procedures they are performing. This proficiency is needed whether in the field performing the sampling or in the laboratory performing the microbiological analyses.

Public Comment

Public review of the monitoring plan is part of the overall public review and comment criterion described in section 2.2.9. States, tribes, or local governments must submit documentation of this public review to EPA.

4.3 Monitoring Report Submission and Delegation

The third performance criterion is to develop a mechanism to collect relevant monitoring information and submit timely reports to EPA and in the case of a state, document any delegation of monitoring responsibilities to local governments.

Report Submission. States, tribes, and local governments must report their monitoring data to the public, EPA, and other agencies in a timely manner. States should coordinate closely with local governments to ensure that monitoring information is submitted in a consistent manner.

States, tribes, and local governments must report their monitoring data annually to EPA. Reported data must be consistent with the list of required data elements in appendix E. The data elements include one-time beach description data, one-time beach program data, one-time station and method identification data, and reoccurring monitoring data. Visit the BEACH Watch web site at http://www.epa.gov/waterscience/beaches and refer to the Beach Guidance document for updates on data submission.

Delegation. If monitoring responsibilities are delegated to local governments, the state grant recipient must describe the process by which the state may delegate to local governments responsibility for implementing the monitoring program and document any specific delegated responsibilities. States must notify EPA annually if there are any changes in delegated responsibilities.

4.4 Assessment Methods and Procedures

Performance Criterion 4 requires the development of detailed methods and assessment procedures. States, tribes, and local governments must

- Adequately address and submit to EPA methods for detecting levels of pathogens and pathogen indicators that are harmful to human health in coastal recreation areas. They must provide documentation to support the validity of methods other than those currently recommended or approved by EPA.

- Identify and submit to EPA assessment procedures for identifying short-term increases in pathogens and pathogen indicators that are harmful to human health in coastal recreation areas.

Adherence to specific procedures for sampling is very important for a successful beach monitoring program. Collection, preservation, and storage of water samples are critical to the results of water quality analyses for bacterial indicators at swimming beaches.

This section and appendix J include a general discussion of basic equipment and techniques that may be used to obtain water samples. The most appropriate sampling procedures should be determined for the beach monitoring program based on the sampling design, the availability of facilities and equipment, and how the samples will be processed. In any case, it is important to develop a written plan or standard operating procedures (SOPs) that document the materials used and the steps performed to obtain the samples and submit them to a laboratory for analysis. Appendix J outlines the EPA-recommended SOPs for sample collection, handling, and subsequent analysis. See also, *Guidance for the Preparation of Standard Operating Procedures* (USEPA, 2001d).

4.4.1 Laboratory Analysis

An important component of the beach monitoring program is selection of a laboratory experienced in performing microbiological techniques, including methods for detecting *E. coli* and enterococci, that can provide results that conform with the established standards for precision and bias (accuracy). It is recommended that an accredited laboratory be used to obtain data when beach advisory or closing decisions are to be made.

Policies and procedures for obtaining necessary laboratory and analytical services should be developed as part of this performance criterion. Analytical laboratories should have the capability to analyze the quantity of samples requested within the required time period, the instrumentation/technique expertise to perform the required analyses, and qualified staff to perform the analyses (USEPA, 1998c). Not only do microbiological techniques call for strict adherence to specified methods, but staff also should avoid introducing unwanted microorganisms into media and thereby producing incorrect results. Facilities should be equipped with proper ventilation and equipment, and surfaces should be kept clean and disinfected regularly. Staff should have received extensive training in a variety of techniques for the detection of heterotrophic bacteria and other microorganisms and should be able to meet the standards set for preparation of sterile media, inoculation procedures, colony counts, and other aspects involved in the analysis of bacterial densities in surface water samples.

The laboratory QA officer should issue and approve SOPs covering general laboratory operations, as well as specific procedures. Copies of all approved laboratory operations SOPs should be kept on file. Such SOPs usually include a discussion of responsibilities for performing and overseeing the work; possible interferences that might affect the analyses; safety considerations; QC activities, equipment, materials, reagents, and standards needed for the analyses; the steps of the procedure in chronological order; an explanation of how data should be

analyzed and reported; references; and associated documents and forms. The laboratory should maintain log books for sample receipt, preparation of standards and media, sample analysis, instrument runs, and instrument maintenance. The laboratory should have an established quality management plan that specifies the quality policy, staff responsibilities, record management, types of assessments performed to evaluate the analyses, and how corrective actions are addressed.

Further discussions of good laboratory practices, requirements for equipment and supplies, training programs for staff, QA/QC issues, and health and safety considerations for microbiological laboratories are provided by Cross-Smiecinski and Stetzenbach (1994), Csuros and Csuros (1999), and Eaton et al. (1995). A capable laboratory should be accredited. Accreditation means that the laboratory has been investigated and found to meet the standards and criteria set by an appropriate accrediting agency, including having qualified personnel, appropriate instrumentation, SOPs, and demonstrated proficiency in the analysis of samples for particular bacterial indicators. Laboratory accreditation is available through state agencies or EPA's National Environmental Laboratory Accreditation Program (NELAP), which oversees state accrediting authorities. Further information on NELAP is available from the National Environmental Laboratory Accreditation Conference (NELAC) at http://www.epa.gov/ttn/nelac. NELAC is a voluntary association of state and federal agencies that was formed to establish and promote mutually acceptable performance standards for the operation of environmental laboratories.

Agency policies and procedures for purchasing analytical services should be reviewed to determine their suitability for implementing the beach monitoring program. Of particular importance are the specification of method requirements that will be used to identify bacterial indicator levels in the water samples, the number of samples that will be submitted for analysis, the frequency of submittals, the schedule and turnaround time for results, deliverables and reporting format, and contractual requirements, including penalty or damage clauses to reduce laboratory default, late data submittals, and improperly performed analyses. Further guidance on soliciting and awarding contracts for analytical services is provided in *EPA's Guide to Laboratory Contracting* (USEPA, 1998c).

4.4.2 Analytical Procedures

This section discusses currently recommended analytical procedures for assessing ambient waters.

For several years EPA has recommended a number of EPA-developed methods for use in testing ambient waters. These methods are described below.

In addition, EPA has proposed to amend the *Guidelines Establishing Test Procedures for the Analysis of Pollutants* under section 304(h) of the Clean Water Act, by adding several analytical procedures for enumerating *Escherichia coli* (*E. coli*) and enterococci to the list of EPA-approved methods at Title 40 of the *Code of Federal Regulations* (CFR) part 136. If EPA has "approved" (i.e., promulgated through rulemaking) standardized testing procedures for a given pollutant, a National Pollutant Discharge Elimination System (NPDES) permit must specify one of the approved testing procedures or an approved alternative test procedure. These methods also can be used in nonregulatory applications.

In August 2001 EPA proposed these new testing procedures in *Guidelines Establishing Test Procedures for the Analysis of Pollutants; Analytical Methods for Biological Pollutants in Ambient Water; Proposed Rule*. These procedures were developed by the voluntary consensus bodies (the American Public Health Association [APHA], American Water Works Association [AWWA], and Water Environment Foundation [WEF]) that jointly publish *Standard Methods for the Examination of Water and Wastewater*, referred to as "Standard Methods: American Society for Testing and Materials (ASTM)," Association of Official Analytical Chemists International (AOAC), and commercial vendors with methods submitted to the EPA Office of Water's Alternate Test Procedure (ATP) program.

The proposed rule would revise 40 CFR Part 136 to add analytical methods for *E. coli*, enterococci, *Cryptosporidium*, and *Giardia* in ambient waters. The rule includes methods published in the *1995 Official Methods of Analysis of AOAC International*, the 20th edition of *Standard Methods*, and the *2000 Edition of the Annual Book of ASTM Standards* (Vols. 11.01 and 11.02). It also includes methods that EPA and commercial vendors, including Hach Company and IDEXX Laboratories and others, have developed.

For beach testing, EPA recommends that states, tribes, and local governments use the EPA-recommended methods described below. The methods identified in the Part 136 rule also would be acceptable. In addition to the methods proposed in Part 136, entities that want to use methods other than the approved ones need to go through the EPA's ATP program, where they should submit their method with validation data. Such documentation supporting the validity of methods other than those currently recommended by EPA must be provided in order to meet performance criterion 4.

Description of Methods

Membrane filtration (MF) and most probable number (MPN) are two types of methods that are currently used for enumerating *E. coli* and enterococci in ambient water. MF is a direct-plating method in which sample dilutions/volumes are filtered through membrane filters that are subsequently transferred to petri plates containing selective primary isolation agar. A second substrate medium is used in the two-step MF procedures to differentiate the target organisms. In MPN tests, the number of tubes or wells producing a positive reaction provides an estimate of the original, undiluted density (concentration) of target organisms in the sample. This estimate of target organisms, based on probability formulas, is termed the most probable number. MPN tests can be conducted in multiple-tube fermentation (MTF), multiple-tube enzyme substrate, or multiple-well enzyme substrate formats.

EPA-Recommended Methods

EPA currently recommends four membrane filter methods for assessing ambient waters and for making decisions concerning the protection of human health at beaches.

Membrane Filter Tests for Enterococci

EPA Method 1600 (mEI media). Method 1600 is a single-step MF procedure that provides a direct count of enterococci in water based on the development of colonies on the surface of a filter when placed on selective mEI agar (USEPA, 1997). This medium, a modification of the mE agar in EPA Method 1106.1, contains a reduced amount of 2-3-5-triphenyltetrazolium chloride, and an added chromogen, indoxyl-β-D-glucoside. This change in ingredients allows for results in 24 hours rather than 48 hours, and it eliminates the second filter transfer step from mE to EIA. In this method, a water sample is filtered, and the filter is placed on mEI agar and incubated at 41 ± 0.5 °C for 24 hours. Following incubation all colonies with a blue halo, regardless of colony color, are counted as enterococci. Results are reported as enterococci per 100 mL.

EPA Method 1106.1 (mE media): EPA Method 1106.1 is a two-step MF procedure that provides a direct count of enterococci in water, based on the development of colonies on the surface of a membrane filter when placed on a selective medium (USEPA, 1985b). A water sample is filtered through a 0.45-μm membrane filter, and the filter is placed on a plate containing selective mE agar. After the plate is incubated at 41 ± 0.5 °C for 48 hours, the filter is transferred to an Esculin Iron Agar (EIA) plate and incubated at 41 ± 0.5 °C for 20 to 30 minutes. After incubation, all pink to red colonies on the mE agar that form a black or reddish-brown precipitate on the underside of the filter when placed on EIA are counted as enterococci. The organism density is reported as enterococci per 100 mL.

Membrane Filter Tests for E. coli

Modified EPA Method 1103.1 (Modified mTEC Media): Modified EPA Method 1103.1 is a single-step MF procedure that provides a direct count of *E. coli* in water, based on the development of colonies on the surface of a filter when placed on a selective modified mTEC medium (USEPA, 1985a). This is a modification of the standard mTEC media that eliminates bromcresol purple and bromphenol red from the medium, adds the chromogen 5-bromo-6-chloro-3-indolyl-β-D-glucuronide, and eliminates the transfer of the filter to a second substrate medium. In this method, a water sample is filtered through a 0.45-μm membrane filter. The filter is placed on modified mTEC agar, incubated at 35 ± 0.5 °C for 2 hours to resuscitate injured or stressed bacteria, and then incubated for 23 ± 1 hours in a 44.5 ± 0.2 °C water bath. Following incubation, all red or magenta colonies are counted as *E. coli*.

EPA Method 1103.1 (mTEC Agar): EPA Method 1103.1 is a two-step procedure that provides a direct count of *E. coli* in water based on the development of colonies on the surface of a membrane filter when placed on a selective nutrient and substrate medium (USEPA, 1985a). EPA originally developed this method to monitor the quality of recreation waters. This method also was used in health studies to develop the bacteriological ambient water quality criteria for *E. coli*. In this method, a water sample is filtered through a 0.45-μm membrane filter, the filter is placed on mTEC agar (a selective primary isolation medium), and the plate is incubated first at 35 ± 0.5 °C for 2 hours to resuscitate injured or stressed bacteria and then at 44.5 ± 0.2 °C for 23 ± 1 hours in a water bath. Following incubation the filter is transferred to a filter pad saturated with urea substrate medium. After 15 minutes all yellow or yellow-brown colonies (occasionally yellow-green) are counted as positive for *E. coli*.

An EPA video, "Improved Enumeration Methods for the Recreational Water Quality Indicators: Enterococci and *Escherichia coli*," demonstrates the four methods currently recommended by EPA, including the mEI and the mE agar methods for enterococci and the modified mTEC and mTEC agar methods for *E. coli*. The purpose of the video is to introduce and demonstrate the improved methods. Accompanying the video is a laboratory manual having the same name that explains all four methods in a step-by-step format (USEPA, 2000b). The laboratory manual also contains color photographs of the target colonies on all media to aid in identification. The video and methods manual are now available to all interested laboratories. Requests for copies of the manual (EPA 821R-97-004) or videotape (EPA 822V-99-001) should be directed to EPA's National Service Center for Environmental Publications (http://www.epa.gov/ncepihom/ or phone 513-489-8190). The manual is also available at http://www.epa.gov/waterscience/beaches or http://www.epa.gov/microbes.

Other Methods Proposed in Part 136 Rule

In the Part 136 proposed rule (*Guidelines Establishing Test Procedures for the Analysis of Pollutants; Analytical Methods for Biological Pollutants in Ambient Water; Proposed Rule)*,

EPA has outlined several additional methods to be used to enumerate *E. coli* and enterococci. Additional information on these methods can be found at http://www.epa.gov/waterscience/methods/.

Most probable number tests for E. coli:
- LTB EC-MUG (Standard Methods 9221B.1/9221F)
- ONPG-MUG (Standard Methods 9223B, AOAC 991.15, Colilert, Colilert-18, and Autoanalysis Colilert)
- CPRG-MUG (Standard Methods 9223B, ColisureTM)

Membrane filter tests for* E. coli*:
- mEndo, LES-Endo, or mFC followed by transfer to NA-MUG media (Standard Methods 9222B/9222G or 9222D/9222G)
- MI agar
- m-ColiBlue24 broth

Most probable number tests for Enterooccci:
- Azide Dextrose/PSE/BHI (Standard Methods 9230B)
- MUG media (ASTM D6503-99, Enterolert)

Beach managers should be aware of the methods that may be used for analyzing the water samples from beaches to meet particular monitoring program objectives. In addition, they should be prepared to advise the laboratory of the intended use of the data and the data quality needs of the project when seeking laboratory services. Otherwise, the laboratory cannot implement performance-based measurement systems (PBMS) effectively or know when it is appropriate to rely on the published methods.

4.4.3 Recommended Sample Collection Techniques

Strict adherence to specific procedures for sampling is critically important for a successful beach monitoring program. This can be accomplished through a detailed plan or SOP for obtaining samples and submitting them for analysis. Proper collection, preservation, and storage of water samples are critical to ensuring the accuracy of the results of water quality analyses for bacterial indicators at swimming beaches. This section and appendix J discuss the basic equipment and techniques that may be used to obtain water samples. Appropriate sampling procedures should be determined for the beach monitoring program based on the sampling design, the availability of facilities and equipment, and how the samples will be processed. For example, sample containers might be sterilized locally before each beach sampling event by the laboratory performing the analyses. These containers also may be provided through a contractor, or an agency might purchase sterile containers from a scientific supply company. In any case, it is important to develop a written plan or SOP that documents the materials used and the steps performed to

obtain the samples and submit them to a laboratory for analysis. Appendix J outlines the EPA-recommended SOPs for sample collection, handling, and subsequent analysis.

4.4.4 Data Verification and Validation

Certain procedures should be used to verify whether the microbiological analyses have correctly estimated the densities of indicator bacteria, to ascertain whether particular requirements for a specified use of the results have been fulfilled, and to determine how the data should be interpreted for decision making. This section discusses some of the important aspects of these procedures, which should be included in the monitoring program design to ensure that the data obtained are usable and defensible. Several iterations through these activities might be necessary to ensure that the data and their interpretation are correct.

Validation Methods

Single laboratory validation refers to the confirmation that particular DQOs for a specified intended use have been fulfilled. Thus, once the data have been confirmed to meet standards and contract requirements, they may be systematically examined to determine their technical usability with respect to the planned objectives. This activity also can provide a level of overall confidence in the reporting of the data based on the methods used. For example, if the wrong medium was used or the incubation temperature limit was exceeded, the data would be assigned a qualifier indicating their uncertainty and would be rejected from further analyses. A report that provides an assessment of the usability of the data, a summary of environmental sample results, and a summary of QC and QA results should be prepared. The report should discuss any discrepancies between the DQOs and the data collected and any effects such discrepancies might have on the ability to meet the DQOs.

Finally, an assessment of data quality should be performed to evaluate whether the data are of the right type, quality, and quantity to support their intended use. This assessment may include reviewing the DQOs and sampling design, conducting a preliminary data review, selecting the statistical test, verifying the assumptions of the statistical test, and drawing conclusions from the data.

Verification Methods

Procedures to verify whether the bacterial indicators were correctly determined should be provided for any method used. Verification involves performing additional tests to identify those colonies found on the membrane filter that provided information. A false positive rate is calculated as the percent of colonies that reacted (were identified as the indicator) but were not actually the indicator. A false negative rate is calculated as the percent of colonies that did not react as anticipated (and so were not identified as the indicator) but were in fact that indicator. False positive and false negative rates for the media used in EPA Methods 1600 and 1103.1 are

provided in those methods. Verification procedures should be used in establishing QC limits on initial use of the procedure, when using a new technician to perform the procedure to ensure that method requirements can be met, whenever any changes are made in how the procedure is performed or in the materials used in the procedure, and always when the results are to be used in evidence for legal proceedings.

Sample records, chain of custody records, and sample tracking records should be reviewed to verify that all the samples collected were analyzed so that the data set will be complete. Data entries and analyses also should be verified. For large quantities of data, spot-checking to detect potential data entry errors should be performed. Additional checks may include graphically displaying data to visually inspect for potential errors, using statistical methods to detect invalid data, and checking for duplicate data entries. Input data may be reviewed for accuracy, bias, completeness, precision, representativeness, or uncertainty. In addition, data reductions and transformations should be reviewed (audited) to ensure that they have been correctly performed. Review of calculations may include rechecking the computations, reviewing the assumptions used and the selection of input data, and checking the input data against the original sources to be sure transcription errors have not occurred. The types of calculations that might be performed on bacterial indicator filter counts to estimate bacterial densities per sample are provided in the EPA methods. Further examples are shown in *Standard Operating Procedure for Recreational Water Collection and Analysis of* E. coli *in Streams, Rivers, Lakes and Wastewater* (IITF, 1999).

The reviewer should document the results and report them to the beach monitoring program management staff. To verify conformance of the data collection effort with the plan, data should pass the specified numerical QC tests (precision and bias limits); the plans should be followed and calculations should be performed correctly; all samples should be treated consistently; and the necessary quantity of data and information relative to the stated DQOs should be obtained (completeness). Any components requiring correction should be corrected if possible, or the data should be rejected and not used to make the decision.

4.5 Use of Predictive Tools in Beach Monitoring Programs

The primary objective of any beach monitoring program is to minimize beachgoers' health risk associated with infectious diseases caused by exposure to pathogenic microbial organisms. Notifications of elevated levels of indicator bacteria are usually based on monitoring of beach waters. Under this system, however, users of recreational waters can be exposed to waterborne pathogens because of inadequate monitoring or delayed notification of monitoring results during periods of poor water quality. The laboratory methods commonly used to detect potentially harmful microorganisms take 24 to 48 hours. During this period, beachgoers might be exposed to harmful pathogens.

To reduce exposure to pathogens, government agencies need tools that can provide a quick, reliable indication of the water quality conditions. Predictive models are one means to provide

these rapid indications. Modeling tools are used to supplement, not replace, monitoring and provide conservative estimates when there is a lag time between sampling the water quality and obtaining results.

A wide range of models are available that could be adapted to support beach advisory decisions. If a beach manager chooses to use a predictive model, the model chosen should be supported by identified selection criteria. Selection of the appropriate model for helping to determine beach advisories and closings depends on the site conditions of the waterbody of concern. Some of the site-specific considerations include the types of sources (point source/nonpoint source), waterbody types, transport and circulation patterns, severity of impairment, and frequency of indicator criteria exceedances. Other issues to consider are the model development and application cost, the accuracy required, the use of the system, the training of staff, user-friendliness, and public outreach and education requirements. In some cases economies of scale can be identified when related analysis and modeling efforts have been initiated in the waterbody of concern. The methodology and screening factors for selecting a model can and should be described in the QA project plan. The selection of the appropriate model may be based on the following screening factors:

- Combined point and nonpoint sources
- Pathogen source characterization
- Dominant mixing and transport processes
- Pathogen concentration prediction
- Ability to provide time-relevant analysis, decision making, and guideline establishment
- Time-relevant use
- Evaluation of unplanned and localized spills
- Documented application to beach and shellfish closures
- Ease of use
- Input data requirements
- Calibration requirements
- Pollutant routing
- Kinetics of pathogen decay

If models are properly developed and applied, simple models for dilution and mixing zone evaluations can be used in making beach advisory or closing decisions. More complex models also can be considered in light of their ability to assess dynamic loading and transport processes. Detailed models can be used in developing a range of decision rules for categories of loading or environmental conditions. These decision rules can be used to address day-to-day operations in a cost-effective and timely manner.

The predictive models currently in use by local agencies vary in their complexity and approach but are generally simple, reliable tools. An example of a commonly-used model is the rainfall-based alert curve, which is a statistical relationship between the amount of rainfall at

representative rainfall gauges in the watershed and the observed bacterial indicator concentration at a specific beach area. This relationship is based on simple regression methods and the frequency of exceeding simultaneous and representative observations of bacterial indicator concentrations and rainfall events. Pathogen data supporting the development of rainfall-based alert curves are generated from the water column concentrations obtained from ambient or targeted monitoring programs. Although these models do not explicitly account for point and nonpoint sources or fate and transport processes, they rely on a direct statistical relationship and provide simple, easy-to-use tools with reasonable accuracy.

In some cases objectives can best be met by using one model, whereas in others a combination of models might be needed. Models are often developed for a particular waterbody type, including rivers and streams, lakes, and offshore ocean waters. When determining the type of model to use, factors such as data needs, application cost, pollutant type, and required accuracy are important to consider.

Appendix K provides examples of currently used models and other predictive tools that could be used to determine the need for a beach closing. The models are divided into two categories—watershed pathogen loading models and pathogen concentration prediction models. The latter category is divided into two additional groups to reflect different waterbody types: (1) rivers and streams and (2) lakes and estuaries. Currently, there is a lack of readily available models that address the coastal nearshore environment; therefore, no models that study the surf zone are included in appendix K.

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